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Foreign Technology Licensing, Productivity, and Spillovers

RICARDO A. LÓPEZ *
Indiana University, Bloomington, IN, USA

Summary. — This paper uses plant-level data from the manufacturing sector of Chile to investigate whether foreign technology licensing generates productivity spillovers to other plants in the same industry and to other plants in vertically related industries (potential suppliers and buyers of output). The results show that licensing in upstream sectors increases productivity of plants that purchase intermediate inputs from them. However, licensing in downstream sectors has a negative effect on productivity of suppliers of intermediate inputs. Finally, there is no evidence of intra-industry spillovers from foreign technology licensing.

Key words — technology licensing, productivity, spillovers, developing countries, Chile

1. INTRODUCTION

Technological change is the main source of economic growth in the long run for both developed and developing countries. But while developed countries innovate and create their own technologies, developing countries acquire technology by copying or importing them from the industrialized world. Technology licensing allows countries to obtain relatively fast and cheap access to new and more advanced technologies. [1] It is easier to import a technology than to develop a completely new technology. The latter requires mastery of the technology while the former does not require complete mastery of it (Westphal, 1982). Several authors emphasize the importance of technology licensing for industrialization. Lall (2000), for example, argues that imported technologies provide "the most important initial input into technological learning in developing countries" (p. 20). Given that technologies change continuously, according to Lall access to imported technologies is "vital to continued technological progress" (p. 20).

Although licensing may benefit the licensee, [2] it might also benefit other firms. Westphal (1982), for example, argues that the mastery of a technology increases productivity "but much of the impact spills over into related activities" (p. 260). The scarce empirical evidence on this issue is, however, not conclusive. While Kathuria (2000) finds positive productivity spillovers from foreign technical capital stock (payments on foreign patents, licenses, and technical assistance fees) in Indian manufacturing, Álvarez *et al.* (2002) do not find any spillover effect from licensing activity in Chilean manufacturing. Both studies focus on intra-industry spillovers; but technology may be also transferred to firms in other industries (Lall, 2000; Stewart & Ghani, 1992; UNCTAD, 1999). Stewart and Ghani (1992) argue that "interactions between suppliers of inputs (capital goods and materials and parts) and purchasers" (p. 423) were very important to diffuse technology in many countries.

Several case studies provide evidence of technology diffusion through buyer–supplier relationships. [3] Perez-Aleman (2002) presents an example for the case of Chile. She describes the collaboration between producers and their suppliers in the Chilean agro-industry. She says that "frequent field visits by the plant's

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technical personnel (at least once a week) to suppliers allowed for timely correction responses to deficiencies to meet the buyer firms quality standards" (p. 46).

This paper examines, for the first time, the existence of both intra-industry and inter-industry productivity spillovers from foreign technology licensing. In particular, it seeks to answer the following question: Do plants benefit from foreign technology licensing by plants in the same industry and from licensing by plants in other industries?

This is an important issue for at least two reasons. First, licensing is more relevant today than ever as a source of technology. Payments in royalties and license fees worldwide increased from less than $4 billion in 1975 to more than $100 billion in 2005. [4] The way in which firms in developing countries acquire technology has changed over the last decades. Firms are relying increasingly more on licensing and technical assistance than in copying and self-teaching (Amsden, 1989). [5] Moreover, inter-industry interactions between firms are more important today than in the past. Firms are increasingly outsourcing components and services from other firms and they closely collaborate with suppliers and customers (UNCTAD, 1999). There is another, and perhaps more important, reason to study this issue. Some countries (e.g., Korea) have allowed technology licensing with the idea that they generate spillover effects, but others (e.g., some Latin American countries) have restricted licensing because they fear that it could make them technologically dependent on the industrialized countries and even slow down technological progress. If licensing does generate positive spillovers then governments might consider implementing policies that facilitate the imports of technology through this mechanism.

Inter-industry productivity spillovers from technology transfer have been studied mostly in the context of multinational corporations (e.g., Blalock & Gertler, 2005, forthcoming; Javorcik, 2004; Javorcik & Spatareanu, 2005, 2006). [6] Most of these studies estimate an equation for plants' productivity as a function of the degree of foreign presence in downstream and upstream industries, as well as the extent of foreign presence in the same industry. Although the results of these studies are not always consistent, most of them find evidence of positive spillovers from multinational corporations operating in downstream sectors. An overlooked aspect of this literature is the possible spillover effect from technology licensing. As Hoekman and Javorcik (2006) argue, spillovers can arise not only from trade and foreign direct investment but also from technology licensing. Thus, unlike previous studies, measures of both foreign presence and technology licensing in the same industry as well as in vertically related industries are included the regression analysis.

This paper also addresses several econometric issues. The regressions control for the degree of export orientation of the sector, and for plant characteristics that may affect productivity, such as the export status of the plant and whether the plant has foreign ownership. The methodology also takes into account plant heterogeneity, and deals with the potential endogeneity of the licensing measures using an instrumental variables approach. Using plant-level data from the manufacturing sector of Chile during 1990–99, the results show that licensing in upstream sectors has a positive and significant effect on plants' productivity while licensing in downstream sectors has a significant negative effect on productivity. Technology licensing does not appear to affect productivity of plants operating in the same sector. These results are robust to different estimation methods as well as the use of alternative measures of licensing activity.

2. DATA AND BASIC PATTERNS

This paper uses plant-level data from the manufacturing sector of Chile during 1990–99, a period in which the GDP expanded at 6.4% annually. [7] As seen in Table 1, imports of foreign technology increased rapidly during the decade. While royalties and license fees accounted for only 0.10% of the GDP during the first half of the 1990s, by the second half of the decade this number had increased to 0.24%. Royalties and license fees continued increasing during the new century reaching 0.37% of the GDP in 2000–04. As seen in the table, Chile today spends more on foreign licenses than Argentina and Brazil, two of the largest semi-industrialized countries in Latin America.

The plant-level data were obtained from the Annual National Industrial Survey (ENIA) carried out by the National Institute of Statistics of Chile (INE). This survey covers Chilean manufacturing plants with 10 or more workers. For each plant and year, the ENIA collects data on production, value added, sales,

Table 1. *Royalties and license fees payments (Percentage of GDP)*

	1980–84	1985–89	1990–94	1995–99	2000–04	1980–2004
Argentina	0.39	0.38	0.18	0.17	0.25	0.28
Brazil	0.01	0.01	0.02	0.13	0.24	0.08
Chile	0.13	0.14	0.10	0.24	0.37	0.20

Source: World Development Indicators, World Bank.

employment and wages (production and non-production), exports, investment, depreciation, energy usage, foreign licenses, and other plant characteristics. In addition, plants are classified according to the International Standard Industrial Classification (ISIC) rev 2. Using 4-digit industry-level price deflators all monetary variables were converted to constant pesos of 1985. The capital stock at the plant level was constructed using the perpetual inventory method for each plant. [8] The survey has, on average, data on more than 4,900 plants. About 6% of this number has foreign ownership.

Table 2 shows the annual distribution of plants by licensing activity for the period 1990–99. On average, 5.3% of the plants use foreign licenses while 94.7% do not. There is an increase in the share of plants using licenses during this period. In 1990 only 4.8% of the plants spent on foreign licenses while in 1999 the share of plants was 5.5%. Although the number of licensees is still small, more Chilean manufacturing plants are relying on licenses as a source of foreign technologies.

The degree of internationalization and the size of the plants are correlated with the use of technology licenses. As seen in Table 3, around 14% of plants with export activity and almost 21% of plants with foreign ownership spend on foreign licenses. In addition, 18.4% of large plants (150 or more workers) use foreign licenses, while only 2.4% among small plants (between 10 and 49 workers) and 7.2% among medium plants (between 50 and 149 workers) do so.

3. METHODOLOGY

This paper studies the existence of spillovers from technology licensing by considering an augmented production function that explicitly incorporates the potential spillover effect from technology licensing. Measures of licensing activity in the same industry in which the plant operates and in vertically related industries are included:

$$y_{ijrt} = \alpha_0 + \alpha_1 k_{ijrt} + \alpha_2 l^{NP}_{ijrt} + \alpha_3 l^{P}_{ijrt} + \beta' \Theta_{jt} + \varepsilon_{ijrt}, \tag{1}$$

where y_{ijrt} is the log of value added of plant i operating in sector j and region r at time t; k_{ijrt} is the log of plant's capital stock, while l^{NP}_{ijrt} and

Table 2. *Distribution of plants by licensing activity*

	Number		% of the Total	
	Licensees	Non-licensees	Licensees	Non-licensees
1990	218	4,356	4.8	95.2
1991	255	4,503	5.4	94.6
1992	254	4,677	5.2	94.8
1993	276	4,760	5.5	94.5
1994	263	4,815	5.2	94.8
1995	277	4,830	5.4	94.6
1996	308	5,139	5.7	94.3
1997	259	4,701	5.2	94.8
1998	276	4,539	5.7	94.3
1999	243	4,157	5.5	94.5
1990–94	253	4,622	5.2	94.8
1995–99	273	4,673	5.5	94.5
1990–99	263	4,648	5.3	94.7

Source: Author's calculations based on the ENIA.

Table 3. *Distribution of plants by licensing activity and type of plant*

	Number		Percentage	
	Licensees	Non-licensees	Licensees	Non-licensees
Exporter	1,435	8,739	14.1	85.9
Non-exporter	1,194	37,738	3.1	96.9
Foreign ownership	587	2,229	20.8	79.2
Domestic	2,042	44,248	4.4	95.6
Small	764	31,715	2.4	97.6
Medium	765	9,869	7.2	92.8
Large	1,100	4,893	18.4	81.6

Source: Author's calculations based on the ENIA. Small: 10–49 employees; Medium: 50–149 employees; Large: 150 or more employees.

l^P_{ijrt} are the number of non-production and production workers (in logs), respectively. The vector Θ_{jt} measures foreign technology licensing in the same industry (S_{jt}) and in downstream (D_{jt}) and upstream (U_{jt}) sectors: $\Theta_{jt} = \{\log(S_{jt}), \log(D_{jt}), \log(U_{jt})\}$.

S_{jt} is measured with two different methods. The first method uses the accumulated payments in royalties and license fees (SL_{ijt}) as a proxy for the stock of knowledge generated by foreign licenses. This total stock is then divided by the sales of the industry:

$$S^{Stock}_{jt} = \frac{\sum_{i\in j} SL_{ijt}}{\sum_{i\in j} Sales_{ijt}}, \tag{2}$$

where $Sales_{ijt}$ are sales of plant i in industry j at time t. The stock of licenses is obtained using the perpetual inventory method for each plant as in Hasan (2002):

$$SL_{ijt} = L_{ijt} + SL_{ijt-1}(1-\delta), \tag{3}$$

where L_{ijt} are royalties and license fees paid at time t, and δ is the rate of depreciation, assumed to be 5%. [9] To determine the starting values for SL, information on royalties and license fees for the year 1979 is used. For plants that entered after 1979, the value of the first payment in royalties and licenses is used as the initial value of SL.

The second method measures S_{jt} using the flow of royalties and license fees:

$$S^{Flow}_{jt} = \frac{\sum_{i\in j} L_{ijt}}{\sum_{i\in j} Sales_{ijt}}. \tag{4}$$

In both cases, the assumption is that the larger the share of license payments (either in the form of stock or as a flow) on total sales in a given industry, the larger the potential spillover effect. The other two technology licensing variables are measured as

$$D^{Stock}_{jt} = \sum_{k,k\neq j} \alpha_{jk} S^{Stock}_{kt}, \quad D^{Flow}_{jt} = \sum_{k,k\neq j} \alpha_{jk} S^{Flow}_{kt}, \tag{5}$$

$$U^{Stock}_{jt} = \sum_{k,k\neq j} \sigma_{jk} S^{Stock}_{kt}, \quad U^{Flow}_{jt} = \sum_{k,k\neq j} \sigma_{jk} S^{Flow}_{kt}, \tag{6}$$

where α_{jk} is the proportion of sector j's output supplied to sector k, and σ_{jk} is the share of inputs purchased by industry j from industry k in total inputs purchased by industry j. [10] The D_{jt} variable attempts to reflect the licensing activity of industries that are supplied by industry j, while the U_{jt} variable measures the licensing activity of industries that supply inputs to industry j.

One limitation of these measures is that royalties and license payments may not reflect the true value of the technology being transferred and its productivity. Pack (2006), for example, explains that licenses expenditures are the outcome of a bargaining process between the buyer and the seller of the technology. But even if expenditures are well recorded, they may underestimate the impact of some technology transfers, since not all contacts with foreign suppliers are necessarily reflected in license fees (Pack, 2006).

Table 4 shows the average of the technology licensing variables over the period 1990–99. The first three columns show the stock of licenses, while the last three show the measures based on the flows of license fees. The stock of licenses as a share of sales ranges from 0.19% for wood products to 11.26% for rubber products. The unweighted average across all industries is 2% while the weighted is 1.4%. Although these numbers are small, the importance of licenses has increased during the

Table 4. *Foreign technology licensing by sector—average 1990–99 (percentages)*

	Stock			Flow		
	Same sector	Downstream sectors	Upstream sectors	Same sector	Downstream sectors	Upstream sectors
Food	0.78	0.26	0.49	0.06	0.02	0.06
Food—miscellaneous	2.05	0.14	0.27	0.20	0.01	0.03
Beverages	2.34	0.01	1.00	0.11	0.00	0.11
Textiles	1.14	0.61	0.27	0.09	0.09	0.04
Apparel	1.69	0.03	0.60	0.27	0.00	0.05
Leather products	0.23	1.82	1.22	0.03	0.20	0.13
Footwear	3.66	0.00	0.45	0.40	0.00	0.06
Wood products	0.19	0.10	0.22	0.04	0.01	0.03
Furniture	0.42	0.08	0.63	0.06	0.01	0.10
Paper	0.85	0.41	0.27	0.18	0.05	0.04
Printing	0.48	0.11	0.62	0.11	0.01	0.12
Industrial chemicals	2.04	0.63	0.32	0.24	0.08	0.05
Other chemicals	5.16	0.12	0.31	0.87	0.01	0.05
Petroleum refineries	0.52	0.20	0.09	0.07	0.03	0.01
Petroleum and coal products	3.24	0.20	0.08	0.49	0.03	0.01
Rubber products	11.26	0.02	0.45	1.00	0.00	0.07
Plastics	1.34	0.67	0.41	0.25	0.08	0.06
Ceramics	0.26	0.69	0.61	0.04	0.05	0.08
Glass	4.13	0.69	0.60	0.48	0.05	0.08
Non-metallic minerals	3.87	0.02	0.31	0.58	0.00	0.05
Iron and steel	0.98	0.49	0.09	0.18	0.06	0.01
Non-ferrous metals	0.24	0.24	0.18	0.03	0.03	0.02
Metal products	0.66	0.30	0.58	0.08	0.03	0.10
Non-electrical machinery	0.81	0.04	0.56	0.15	0.00	0.08
Electrical machinery	2.81	0.07	0.22	0.26	0.01	0.04
Transport equipment	0.31	0.00	0.41	0.05	0.00	0.07
Professional equipment	2.64	0.09	0.40	0.23	0.01	0.06
Other manufacturing	1.95	0.09	0.40	0.16	0.01	0.06

Source: Author's calculations based on plant-level data and the input–output table of Chile.

decade on more than 30% using the unweighted average and 19% using the weighted. The variables based on flows of licenses are much smaller, but the order of industries remains very similar.

The values for the downstream and upstream measures are small but there are differences across sectors. For example, the downstream variable is relatively high for leather but almost insignificant for footwear and transport equipment. The upstream variable, on the other hand, is relatively high for leather, beverages, and printing but it is low for petroleum and coal products.

Before estimating (1) it is convenient to rewrite it as

$$y_{ijrt} - (\alpha_1 k_{ijrt} + \alpha_2 l^{NP}_{ijrt} + \alpha_3 l^{P}_{ijrt}) = \alpha_0 + \beta' \Theta_{jt} + \varepsilon_{ijrt}, \quad (7)$$

and using the standard definition of the log of total factor productivity (TFP):

$$\log(\mathrm{TFP}_{ijrt}) = \alpha_0 + \beta' \Theta_{jt} + \varepsilon_{ijrt}. \quad (8)$$

To measure TFP, a Cobb–Douglas production function for each 3-digit level industry is estimated using the method proposed by Olley and Pakes (1996) and later modified by Levinsohn and Petrin (2003), which corrects the simultaneity bias associated with the fact that productivity is not observed by the econometrician but it may be observed by the firm. The residuals of these regressions correspond to the measure of productivity. [11]

Several estimation issues need to be addressed. First there may be plant characteristics as well as industry-level variables that may affect plant-level productivity. This problem is addressed by including a vector of plant-level control variables, X_{ijrt-1}, lagged one period to avoid potential simultaneity problems, and a vector of industry-level variables, Z_{jt}:

$$\log(\text{TFP}_{ijrt}) = \alpha_0 + \beta'\Theta_{jt} + \lambda' X_{ijrt-1} + \theta' Z_{jt} + \varepsilon_{ijrt}. \qquad (9)$$

The vector X_{irjt-1} includes a dummy variable equal to one if the plant exports; a dummy variable equal to one if the plant has foreign ownership; and the level of licenses (either the stock or the flow) as a fraction of sales for each plant. The vector Z_{jt} includes the Herfindahl index to control for the effect of concentration on productivity, [12] the exports to sales ratio of the sector, and measures of foreign presence in the industry and in vertically related industries. [13] These last control variables are included since exporting and foreign ownership may be correlated with technology licensing (see Table 3), but they may be also correlated with productivity. The foreign technology licensing variables may pick up the effect of these two factors if we do not control for them.

The theory is not entirely clear about the exact relationship between concentration and productivity (Nickell, 1996), so the estimated coefficient of the Herfindahl index may be either positive or negative. The estimate for the export orientation of the sector may be positive if, for example, there are positive spillover effects from exporting, but it may be negative if exports increase the price of some specialized inputs used by plants in the industry. Foreign presence is controlled using three measures. The first captures the extent of foreign presence in the same sector the plant operates [14]:

$$\textit{FDI Same Sector}_{jt} = \frac{\sum_{i\in j} \textit{Foreign Share}_{ijt} * Y_{ijt}}{\sum_{i\in j} Y_{ijt}}, \qquad (10)$$

where $\textit{Foreign Share}_{ijt}$ is the percentage of foreign ownership in plant i operating at industry j in year t; and Y_{ijt} is the output of the plant. The second measure captures the foreign presence in sectors that are supplied by industry j (downstream sectors):

$$\textit{FDI Downstream Sectors}_{jt} = \sum_{k,k\neq j} \alpha_{jk} * \textit{FDI Same Sector}_{kt}, \qquad (11)$$

where α_{jk} is, as before, the proportion of sector j's output supplied to sector k. The third measure reflects the degree of foreign presence in upstream sectors:

$$\textit{FDI Upstream Sectors}_{jt} = \sum_{k,k\neq j} \sigma_{jk} * \textit{FDI Same Sector}_{kt}, \qquad (12)$$

where σ_{jk} is the share of inputs purchased by industry j from industry k in total inputs purchased by industry j.

A second estimation issue is that there may be unobserved plant characteristics (e.g., managerial ability) that can make some plants more productive. If these unobserved plant effects are time-invariant, we can rewrite the error term in (9) as $\varepsilon_{ijrt} = u_{ijrt} + \omega_i$, where ω_i is the unobserved plant-specific time-invariant effect and u_{ijrt} is an error term. Therefore, (9) becomes

$$\log(\text{TFP}_{ijrt}) = \alpha_0 + \beta'\Theta_{jt} + \lambda X_{ijrt-1} + \theta Z_{jt} + u_{ijrt} + \omega_i. \qquad (13)$$

Following the standard practice in the literature of spillovers from multinational corporations (e.g., Javorcik, 2004), the unobserved fixed effect is eliminated by estimating the equation in first differences.

A third issue is that there may be unobserved industry and region characteristics that may make some plants more productive. In addition, there may be aggregate shocks that may affect the productivity of plants. These effects are controlled by including a full set of three-digit ISIC sector, region, and year dummy variables.

A fourth estimation issue is a potential endogeneity problem. Suppose, for example, that more productive sectors spend more on foreign licenses, or that the more productive suppliers self-select and provide inputs to sectors that spend more on foreign licenses. The residual u_{ijrt} will be correlated with the licensing measures. We use instrumental variables (IV) estimation method to address this issue. We instrument the three technology licensing variables, in first differences, using one and two lags of the levels of each of the three variables. [15]

Finally, estimating a regression with plant-level data but including sector time-varying variables may underestimate the standard errors (Moulton, 1990). To correct this problem, standard errors are clustered at the 3-digit sector-year level.

Table 5. *Productivity spillovers from foreign technology licensing*

	Licenses all plants—stock			Licenses all plants—flow		
	OLS (1)	FD (2)	FD-IV (3)	OLS (4)	FD (5)	FD-IV (6)
Licenses same sector (S)	−0.119	−0.047	−0.035	0.005	−0.012	−0.022
	(3.06)**	(1.66)***	(0.79)	(0.40)	(0.95)	(1.26)
Licenses downstream sectors (D)	−0.133	−0.185	−0.228	0.002	−0.141	−0.248
	(2.84)**	(4.62)**	(5.19)**	(0.05)	(4.65)**	(5.92)**
Licenses upstream sectors (U)	−0.035	0.578	0.764	−0.055	0.237	0.400
	(0.53)	(6.11)**	(6.48)**	(1.44)	(5.63)**	(6.01)**
Herfindahl index	−0.071	−0.277	−0.277	−0.130	−0.275	−0.277
	(1.31)	(6.01)**	(6.13)**	(2.28)*	(5.50)**	(5.64)**
FDI same sector	0.008	−0.003	−0.002	0.012	−0.005	−0.002
	(1.60)	(0.67)	(0.33)	(2.12)*	(1.00)	(0.43)
FDI downstream sectors	0.031	−0.015	0.024	0.030	−0.064	0.023
	(0.78)	(0.38)	(0.59)	(0.67)	(2.20)*	(0.58)
FDI upstream sectors	0.013	0.229	0.177	0.046	0.363	0.327
	(0.34)	(4.11)**	(3.01)**	(1.20)	(6.64)**	(5.46)**
Exports sector	0.032	−0.042	−0.015	−0.004	−0.075	−0.045
	(1.07)	(1.04)	(0.33)	(0.14)	(2.01)*	(1.09)
Exporter dummy	0.462	−0.013	−0.012	0.466	−0.017	−0.016
	(16.43)**	(0.77)	(0.70)	(16.51)**	(0.98)	(0.94)
Foreign ownership dummy	0.259	0.050	0.051	0.278	0.050	0.052
	(9.50)**	(1.28)	(1.31)	(9.97)**	(1.27)	(1.29)
Licenses/sales	1.613	1.345	1.346	3.866	0.494	0.465
	(7.48)**	(2.76)**	(2.77)**	(2.37)*	(1.52)	(1.41)
R-squared	0.517	0.098	0.096	0.515	0.087	0.079
Number of observations	33,821	26,740	26,740	33,821	26,740	26,740

Absolute value of *t* statistics in parentheses. **, *, ***: significant at 1%, 5%, and 10%. Three-digit sector, region, and year dummy variables were included but not reported. Standard errors were clustered at the sector-year level.

4. RESULTS

Table 5 shows the results of estimating Eqn. (13) with three different methods: OLS, first differences, and first differences with instrumental variables. Columns (1)–(3) use the stock of licenses to measure spillovers, while columns (4)–(6) use the flow of licenses. Looking at the control variables first, plants with larger stocks of knowledge, as measured by the accumulated flow of foreign licenses, have higher productivity levels. Plants that purchase intermediate inputs from sectors with relatively high foreign presence also have higher productivity. It is also observed that the estimate for the Herfindahl concentration index is negative, suggesting that more competition is associated with higher levels of productivity. [16]

The estimates for the technology licensing variables are not always positive and significant. There is evidence of positive spillovers from technology licensing in upstream sectors. The estimates indicate that a 1%-increase in the stock of licenses in upstream sectors increases productivity of plants in downstream sectors by a range of 0.58–0.76%. But the estimates for licenses in downstream sectors are negative and significant. [17] A 1%-increase in the stock of licenses in downstream sectors decreases productivity of plants in upstream sectors by 0.1–0.2%. The estimates for licenses in the same sector are negative, but not significant in most of the cases, which is consistent with the findings of Álvarez *et al.* (2002).

The positive effect of technology licensing in upstream sectors suggests that plants may become more productive by gaining access to higher quality, or less costly, inputs, produced by buyers of foreign technologies. [18]

One reason for the negative effect from downstream licenses could be that when a plant buys a foreign technology through a license it increases its demand for imported inputs relative to domestic inputs. Therefore, when licensing activity increases in a given sector, the output of plants that provide intermediate inputs to that sector falls, which, in the presence of economies of scale, reduces measured productivity. This may occur if the supplier of the technology sells the technology in a package that includes both technological components and non-technological components such as intermediate inputs, [19] or because domestic suppliers do not have the capabilities or the capacity to produce the quality and quantity of intermediate inputs demanded by licensees. [20] To test if this is the case, we estimate the effect of increasing royalties and license fees (both as a stock and as a flow) as a share of sales, on the fraction of inputs that is imported, controlling for productivity, size (number of employees), export status, foreign ownership, and industry, year, and region unobserved effects. The results, not presented here, show that an increase in the fraction of royalties to sales significantly increases the share of imported inputs on total inputs even after controlling several plant characteristics. This suggests that there might be a complementarity between the acquisition of foreign technology through licenses and the use of imported inputs. It is also possible that the negative backward spillover effect is related to the increase in competition that technology licensing may bring. An increase in market competition may force non-licensees to reduce their output, which may decrease the demand for local intermediate inputs, thereby diminishing the backward linkage effect. [21]

One possible explanation for the null effect of licenses in the same sector is that technology adoption is not an easy process. It requires learning and mastery, which demands time and resources. Learning is highly specific and so a technology used by one firm may not be successfully used by other firms (Lall, 2000; Nelson, 1987). Moreover, technology licensing may increase competition in the market and place an upward pressure on the cost of labor or some specialized inputs, which may offset the potential positive effect of licenses on productivity of other firms in the same industry. Another explanation is that an increase in licensing activity may reduce the number of plants that find it profitable to adopt the same technology. This idea is commonly found in the literature on technology diffusion. [22] Two types of models are potentially helpful here. The first group of models, refereed as "stock models" (e.g., Reinganum, 1981a, 1981b), is based on the idea that as the number of firms that adopt a technology increases, the benefits of the marginal adopter go down. Thus, there will be a point at which technology adoption is not profitable anymore. The second group, known as "order models" (e.g., Fudenberg & Tirole, 1985), is based on the idea that the order in which firms adopt a technology determines the net return the firm can obtain from it. Earlier adopters get the higher net returns.

Since a significant fraction of royalties and license payments occur between foreign affiliates and its parents (Radosevic, 1999), it is important to distinguish between foreign licenses by domestic plants and licenses by foreign-owned plants. We measure the licensing activity in the same industry by domestic plants as

$$SD_{jt}^{Stock} = \frac{\sum_{i\in j} D_{ijt} * SL_{ijt}}{\sum_{i\in j} Sales_{ijt}},$$

$$SD_{jt}^{Flow} = \frac{\sum_{i\in j} D_{ijt} * L_{ijt}}{\sum_{i\in j} Sales_{ijt}}, \quad (14)$$

where D_{ijt} is a dummy equal to one if the plant is a domestic plant and 0 otherwise. Similarly we define the SF_{jt} variable (both stock and flow) by using payments on licenses by foreign-owned plants only. The downstream and the upstream variables are defined as in Eqns. (5) and (6).

The results are presented in Table 6. The distinction does not make, in general, much difference. Licensing by both domestic plants and foreign-owned plants generate positive effects on productivity of plants in downstream sectors and a negative effect on productivity of plants in upstream sectors. The estimate for licenses in the same sector is generally negative but rarely significant. The only significant difference appears to be for the stock of licenses in upstream sectors. Licensing by domestic plants in upstream sectors generates a significantly higher positive effect on plants' productivity in downstream sectors than licensing by foreign-owned plants.

5. EXTENSIONS AND ROBUSTNESS CHECKS

5.1 *Effects by types of plants*

It is possible that spillovers from technology licensing affect plants differently depending on their ownership or size. For example, if domestic plants are relatively less productive than foreign-owned plants, then they may have more room to improve their performance and may benefit more from technology diffusion. In this

Table 6. *Spillovers from domestic licensees vs. foreign-owned licensees*

	Stock			Flow		
	OLS	FD	FD-IV	OLS	FD	FD-IV
Licenses same sector domestic	−0.105	−0.036	0.004	−0.013	−0.006	−0.018
	(5.03)**	(1.71)***	(0.06)	(1.77)***	(0.75)	(1.35)
Licenses downstream domestic	−0.068	−0.106	−0.155	0.075	−0.086	−0.197
	(1.96)***	(3.82)**	(3.71)**	(5.06)**	(3.23)**	(4.69)**
Licenses upstream domestic	0.027	0.400	0.677	−0.069	0.150	0.137
	(0.69)	(7.48)**	(5.39)**	(3.66)**	(4.69)**	(2.38)*
Licenses same sector foreign	−0.016	−0.014	−0.017	0.012	−0.008	−0.004
	(1.83)***	(2.09)*	(1.26)	(2.02)*	(1.46)	(0.47)
Licenses downstream foreign	−0.065	−0.129	−0.132	−0.030	−0.030	−0.050
	(1.11)	(3.10)**	(2.25)*	(1.07)	(1.15)	(1.36)
Licenses upstream foreign	−0.005	0.254	0.275	0.018	0.077	0.140
	(0.10)	(7.49)**	(4.97)**	(0.63)	(2.79)**	(3.43)**
Herfindahl index	−0.085	−0.275	−0.260	−0.114	−0.282	−0.290
	(1.68)***	(6.00)**	(5.32)**	(2.08)*	(5.60)**	(5.32)**
FDI same sector	0.005	−0.003	0.002	0.007	−0.006	−0.006
	(0.93)	(0.62)	(0.28)	(1.30)	(1.28)	(1.02)
FDI downstream sectors	0.035	0.043	0.101	0.063	−0.080	0.014
	(0.62)	(0.91)	(1.78)***	(1.24)	(2.32)*	(0.29)
FDI upstream sectors	−0.005	0.176	0.139	0.033	0.357	0.314
	(0.11)	(3.31)**	(2.18)*	(0.77)	(6.62)**	(4.91)**
Exports sector	0.042	−0.047	0.013	0.007	−0.089	−0.084
	(1.42)	(1.18)	(0.22)	(0.22)	(2.45)*	(2.13)*
Exporter dummy	0.462	−0.015	−0.013	0.465	−0.016	−0.016
	(16.48)**	(0.86)	(0.76)	(16.47)**	(0.95)	(0.93)
Foreign ownership dummy	0.260	0.047	0.048	0.149	0.049	0.047
	(9.54)**	(1.22)	(1.21)	(2.33)*	(1.24)	(1.17)
Stock licenses/sales	1.612	1.363	1.371	3.879	0.475	0.515
	(7.48)**	(2.80)**	(2.84)**	(2.37)*	(1.44)	(1.56)
R-squared	0.517	0.106	0.093	0.516	0.087	0.076
Number of observations	33,821	26,740	26,740	33,821	26,740	26,740

Absolute value of *t* statistics in parentheses. **, *, ***: significant at 1%, 5%, and 10%. Three-digit sector, region, and year dummy variables were included but not reported. Standard errors were clustered at the sector-year level.

case, we would expect that productivity of domestic plants increases more than productivity of foreign affiliates. If, however, the lower productivity of domestic plants reflects low levels of absorptive capacity, then they might be less likely to absorb knowledge and benefit from spillovers. Moreover, competition effects generated by technology licensing by other plants may affect domestic plants more than foreign-owned plants. It is, therefore, not clear which group should benefit more from spillovers. There may be also systematic differences across plants with different sizes, but again we do not know which group should be affected more.[23]

To better understand the relationship between spillovers from foreign technology licenses and productivity, Eqn. (13) is estimated separately for the sub sample of domestic plants and the sub sample of foreign-owned plants. The results, using the stock of licenses to construct the spillover variables, are presented in Table 7. Columns (1)–(3) show that licenses in upstream sectors generate positive spillover effects to domestic plants, while licenses in downstream sectors generate negative effects. There seems to be also a negative effect of licensing in the same sector, but the estimate is not significant when instrumental variables are used. For the case of foreign-owned plants, presented in columns (4)–(6), most of the estimates become not statistically significant, suggesting that foreign-owned plants are much less affected by spillovers from foreign technology licensing. Looking at the control variables, we see some other differences. For example,

Table 7. *Productivity spillovers by type of ownership using stock of licenses*

	Sample domestic			Sample foreign owned		
	OLS (1)	FD (2)	FD-IV (3)	OLS (4)	FD (5)	FD-IV (6)
Licenses same sector	−0.108	−0.058	−0.055	−0.170	0.007	0.117
	(2.70)**	(2.04)*	(1.22)	(2.66)**	(0.10)	(0.91)
Licenses downstream sectors	−0.135	−0.178	−0.223	−0.062	−0.308	−0.322
	(2.82)**	(4.48)**	(5.19)**	(0.57)	(2.33)*	(1.85)***
Licenses upstream sectors	−0.027	0.592	0.773	−0.258	0.253	0.399
	(0.41)	(6.21)**	(6.57)**	(1.91)***	(1.17)	(1.37)
Herfindahl index	−0.086	−0.284	−0.284	0.088	−0.112	−0.113
	(1.58)	(6.19)**	(6.33)**	(0.79)	(0.99)	(0.96)
FDI same sector	0.006	−0.004	−0.002	0.296	0.025	0.021
	(1.11)	(0.71)	(0.38)	(6.10)**	(0.77)	(0.62)
FDI downstream sectors	0.030	−0.019	0.022	−0.054	0.003	0.009
	(0.75)	(0.49)	(0.55)	(0.64)	(0.04)	(0.09)
FDI upstream sectors	0.023	0.229	0.177	−0.080	0.166	0.189
	(0.57)	(4.08)**	(2.97)**	(0.83)	(1.30)	(1.57)
Exports sector	0.033	−0.054	0.028	0.004	0.175	0.196
	(1.10)	(1.28)	(0.58)	(0.07)	(3.31)**	(3.69)**
Exporter dummy	0.469	−0.024	−0.023	0.309	0.104	0.102
	(16.11)**	(1.37)	(1.29)	(6.89)**	(1.60)	(1.56)
Stock licenses/sales	1.737	1.375	1.373	1.502	1.330	1.329
	(5.54)**	(2.46)*	(2.46)*	(4.68)**	(1.44)	(1.43)
R-squared	0.504	0.105	0.103	0.655	0.062	0.059
Number of observations	31, 865	25, 199	25, 199	1, 956	1, 541	1, 541

Absolute value of *t* statistics in parentheses. **, *, ***: significant at 1%, 5%, and 10%. Three-digit sector, region, and year dummy variables were included but not reported. Standard errors were clustered at the sector-year level.

foreign presence in upstream sectors appears positively correlated with productivity of domestic plants but uncorrelated with productivity of foreign affiliates. On the contrary, exports are positively correlated with productivity of foreign-owned plants but not correlated with productivity of domestic ones.

Looking at the effects by size in Table 8, again using the stock of licenses, we see that small, medium, and large plants experience a positive effect from licensing in upstream sectors and a negative effect from licensing in downstream sectors. Most control variables have similar effects on these three groups of plants, except for the case of the ratio stock of licenses over sales. It appears that an increase in the stock of licenses increases productivity of small plants, but not that of medium and large plants.

5.2 *Robustness checks*

It is possible that the results are driven by a few outliers. For example, according to Table 4, the sector producing rubber products has a stock of licenses well above the stock of other manufacturing sectors. To verify that the results are not driven by outliers, all the coefficients are re-estimated dropping the sectors that have large usage of licenses relative to the median or the mean (one standard deviation above).[24] In both cases the results, not shown here, do not change much, which confirms that the evidence of spillover effects does not depend on the inclusion of sectors highly intensive in technology licensing.

Finally, it is also possible that royalties and license fees do not reflect the amount of technology being transferred, or its productivity. Thus, we use an alternative approach, which consists on measuring licensing activity using the number of licensees divided by the total number of plants operating in that particular industry and year:

$$SN_{jt} = \frac{NL_{jt}}{NP_{jt}},$$

where NL_{jt} is the number of licensees in industry j at time t, and NP_{jt} is the total number of plants in the same industry and period. This method gives similar qualitative results. There is a positive and significant effect of licensing

Table 8. *Productivity spillovers from foreign technology licensing by size using stock of licenses*

	Small			Medium			Large		
	OLS	FD	FD-IV	OLS	FD	FD-IV	OLS	FD	FD-IV
Licenses same sector	−0.134	−0.046	−0.038	−0.073	−0.019	0.013	−0.099	0.110	−0.128
	(3.13)**	(1.33)	(0.74)	(1.72)***	(0.53)	(0.23)	(3.07)**	(1.93)***	(1.54)
Licenses downstream sectors	−0.145	−0.139	−0.205	−0.038	−0.208	−0.232	−0.156	−0.349	−0. 352
	(2.83)**	(3.26)**	(4.46)**	(0.71)	(4.43)**	(4.45)**	(3.43)**	(4.27)**	(3.86)**
Licenses upstream sectors	−0.023	0.512	0.637	0.020	0.674	0.899	0.007	0.655	0.991
	(0.31)	(5.59)**	(5.31)**	(0.28)	(5.81)**	(6. 63)**	(0.11)	(4.75)**	(5.40)**
Herfindahl index	−0.109	−0.250	−0.258	−0.083	−0.328	−0.330	−0.021	−0.263	−0.241
	(1.86)***	(5.09)**	(5.40)**	(1.33)	(5.28)**	(5. 45)**	(0.45)	(2.81)**	(2.69)**
FDI same sector	0.021	0.001	0.002	0.000	−0.009	−0.007	0.009	−0.005	0.000
	(3.49)**	(0.23)	(0.45)	(0.10)	(0.96)	(0.74)	(1.33)	(0.70)	(0.02)
FDI downstream sectors	0.038	−0.033	0.018	0.001	0.000	0.029	−0.077	0.022	0.039
	(0.83)	(0.85)	(0.44)	(0.01)	(0.00)	(0.64)	(1.59)	(0.33)	(0.57)
FDI upstream sectors	−0.003	0.185	0.156	−0.011	0.263	0.211	0.115	0.295	0.199
	(0.05)	(3.46)**	(2.57)*	(0.24)	(3.73)**	(2. 87)**	(2.16)*	(3.55)**	(2.29)*
Exports sector	0.035	−0.054	−0.034	0.044	−0.014	0.024	0.013	−0.018	0.012
	(1.07)	(1.33)	(0.76)	(1.25)	(0.29)	(0.45)	(0.33)	(0.32)	(0.19)
Exporter dummy	0.299	0.005	0.006	0.138	−0.023	−0.021	0.069	−0.025	0.024
	(12.15)**	(0.22)	(0.26)	(7.51)**	(0.88)	(0.79)	(2. 85)**	(0.74)	(0.74)
Foreign ownership dummy	0.218	−0.017	−0.015	0.213	0.121	0.125	0.123	0.053	0.050
	(5.45)**	(0.30)	(0.26)	(4.83)**	(1.65)***	(1.70)***	(3. 64)**	(0.96)	(0.90)
Licenses/sales	0.297	1.567	1.566	1.357	1.131	1.141	1.475	0.447	0.441
	(0.78)	(2.39)*	(2.39)*	(4.93)**	(1.14)	(1.13)	(7. 25)**	(0.75)	(0.72)
R-squared	0.452	0.085	0.083	0.588	0.132	0.129	0.710	0.137	0.130
Number of observations	20,632	15,877	15,877	8,381	6,851	6,851	4,808	4,012	4,012

Absolute value of *t* statistics in parentheses. **, *, ***: significant at 1%, 5%, and 10%. Three-digit sector, region, and year dummy variables were included but not reported. Standard errors were clustered at the sector-year level. Small: 10–49 employees; Medium: 50–149 employees; Large: 150 or more employees.

in upstream sectors on plants' productivity. This means that plants that purchase inputs from sectors intensive in foreign technology licensing achieve higher productivity. In contrast, firms do not benefit, and indeed are hurt, by licensing activities in downstream industries. [25]

6. CONCLUSIONS

This paper shows that foreign technology licensing has significant productivity spillover effects. In particular, we find significant productivity improvements for plants that purchase inputs from sectors highly intensive in foreign technology licensing. We discover, however, that licensing in downstream sectors has a negative and significant effect on productivity of buyers of output, while technology licensing appears to have no effect on productivity of plants operating in the same sector.

Technology licensing might not increase productivity of plants operating in the same sector because technology acquisition requires learning, which is not easy to achieve and difficult to transfer. Moreover, licensing may increase the level of competition in the industry, increasing the cost of labor and some specialized inputs, which affects productivity negatively. These effects may offset the potential positive spillover effect from buyers of inputs. The negative spillover effect of licensing in downstream sectors may be due to the complementarity between foreign technologies and imported intermediate inputs. Specifically, when plants acquire foreign technologies they appear to increase their demand for imported intermediate inputs and decrease their demand for domestic inputs. These effects then reduce the output of input suppliers and, thereby, their productivity. These results are robust to the inclusion of controls for the level of concentration of the industry, the degree of foreign presence in the same sector and in downstream and upstream sectors, the export orientation of the sector, and the inclusion of plant characteristics. It is also robust to different estimation methods that take into account plants' heterogeneity and the potential endogeneity of the technology licensing measures.

The positive spillover effect from technology licensing in upstream sectors suggests that a subsidy on imports of technology in sectors that provide inputs to plants in the domestic market might be justified. The negative effect of licenses in downstream sectors suggests that to fully benefit from technology licensing spillovers, suppliers must have the capabilities to produce high-quality inputs at low prices.

The results of this paper suggest that we do not fully understand how licensing may generate productivity spillovers, either positive or negative. We need firm-level studies that analyze in detail the interactions between licensees and their suppliers, buyers of output, and competitors. The data used in this paper do not allow us to identify individual relationships between firms. Moreover, the sector-level linkages this paper assumes are based on input–output table coefficients (i.e., using products relationships), which might not reflect technological linkages accurately. Therefore, it would be helpful to develop measures of technological linkages between sectors. Furthermore, license fees may well be the result of a bargaining process between the buyer and the seller of the technology (Pack, 2006), and may not reflect the true value of the technology being transferred and its productivity. Finally, it would be interesting to see if the findings of this paper hold for countries that have used licensing extensively as a source of foreign technologies.

NOTES

1. Technology licensing is also used when capital is scarce or when the country is sensitive to foreign ownership (Duysters & Hagedoorn, 2000).

2. Several studies based on plant or firm-level data find a positive correlation between licensing and some measure of firm performance, such as size (e.g., Giannitsis, 1991; Montalvo & Yafeh, 1994; Mytelka, 1978; Vishwasrao & Bosshardt, 2001), productivity and capital accumulation (e.g., Álvarez, Crespi, & Ramos, 2002; Kiyota & Okazaki, 2005; Yasar & Paul, 2007), and export orientation (e.g., Álvarez & López, 2004, 2005).

3. Enos and Park (1988) and Amsden (1989) discuss several cases of technology transfer from Korean firms to domestic suppliers and customers.

4. Source: World Development Indicators (World Bank).

5. It is also possible that as intellectual property rights become stronger, licensing becomes relatively more attractive than exports and FDI (Hoekman & Javorcik, 2006; Smith, 2001). This can make licensing an even more important channel for technology diffusion.

6. Inter-industry productivity spillovers have also been studied in the context of exporting. Álvarez and López (2006), for example, find positive productivity spillover effects from exporting in vertically related industries.

7. Author's calculations based on data from the Central Bank of Chile.

8. For the majority of plants, an initial value of the capital stock was available. This initial value was used to construct the capital stock data by adding investment and subtracting depreciation for each type of capital (machinery and equipment; buildings; and vehicles). For a small group of plants it was not possible to construct the stock of capital, so they were dropped from the data set.

9. Hasan (2002) assumes a rate of depreciation of 6%. We also calculated the stocks using a depreciation rate of 10%. The results, however, do not change if this depreciation rate is used.

10. We calculate these coefficients using data from the input–output matrix of Chile, constructed by the Central Bank of Chile, at the 3-digit ISIC level for the year 1996. Given that we are interested in linkages within the country and across productive sectors, we exclude the output for final consumption as well as the imports of intermediate products.

11. As a robustness check, we also measure total factor productivity from production functions estimated using OLS. The results, not shown here, do not change significantly.

12. The Herfindahl index is calculated as the sum of the squares of the market shares of all plants, including foreign-owned, operating in the sector in a given year. Aghion, Bloom, Blundell, Griffith, and Howitt (2005) use an alternative method to control for the level of competition. Their measure is defined as one minus the average over all plants of the Lerner index, which is

computed at the plant level as operating profits net of financial cost divided by sales. As a robustness check, we estimate the regressions using this alternative measure. The coefficient is never statistically significant, and the results of this paper do not change in a significant way.

13. All these industry-level control variables are included in logs.

14. See Javorcik (2004).

15. See Cameron and Trivedi (2005, chap. 22).

16. Similar result was found by Javorcik and Spatareanu (2006).

17. Negative backward spillovers have been found in the context of wholly-owned multinational corporations (e.g., Javorcik & Spatareanu, 2006).

18. This argument has been mentioned in the context of spillovers from foreign direct investment (e.g., Javorcik, 2004).

19. This is indeed very common. See, for instance, Dahlman and Westphal (1982), Bhattacharya (1985), and Arora (1996).

20. The UNCTAD report (1999) mentions that in some export-processing zones both local and domestic firms import a high proportion of their inputs because local suppliers cannot "match the quality, variety, and cost standards" (p. 212).

21. This argument has been proposed by Lin and Saggi (2005) in the context of multinational firms.

22. See, for example, Karshenas and Stoneman (1993), and Stoneman (2002).

23. Aitken and Harrison (1999), for example, show that a higher foreign presence in an industry harms small plants more than large plants in Venezuela, suggesting that the impact of productivity spillovers may depend on the size of the plants.

24. Sectors that are one standard deviation above the median include rubber products, and other chemicals. Sectors that are one standard deviation above the mean include, in addition to rubber and other chemicals, footwear, glass, and non-metallic minerals.

25. Due to space limitations, these results are not presented here, but are available upon request.

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